An online summer course for prospective international students to remediate deficiencies in Math prior knowledge: the case of ALEKS

Dirk Tempelaar, Bart Rienties, Martin Rehm, Joost Dijkstra, Mark Arts, and Geke Blok

Maastricht University, Faculty of Economics and Business Administration
PO Box 616, 6200 MD Maastricht, the Netherlands
D.Tempelaar@KE.UNIMAAS.NL

Abstract. This paper is based on the experiences with remedial online learning from a national collaboration initiative of University of Amsterdam, Erasmus University and Maastricht University in the Netherlands, called ‘Web-spijkeren’ (http://www.web-spijkeren.nl/). This project, supported by grants for educational innovation of SURF, the Dutch higher education and research partnership organisation for ICT, aims at developing electronic tests and tutorials for prospective students. Increased heterogeneity of prospective students causes study planning problems. Adaptive testing and remedial teaching might mitigate these problems. The summer course described in this contribution is based on the tool ALEKS: Assessment and Learning in Knowledge Spaces. Knowledge space theory is a branch of mathematical cognitive science that is especially suitable in the design of adaptive diagnostic tests and tutorials for remedial learning in highly structured domains as mathematics. This contribution describes both the foundations of the tool ALEKS, and the usage of ALEKS in our summer course.
1 Introduction

Acceptance to a bachelor or master program has traditionally been based on a required (combination of) degree(s), experience and/or skills. However, due to increasing internationalization of students (e.g. 60 per cent of enrolment at Faculty of Economics and Business Administration at Maastricht University is by international students), the introduction of the Bachelor-Master structure in Europe, and the new accreditation procedures by the Treaty of Bologna, heterogeneity of enrolled students has increased. Although a foreign student formally should be accepted to a study program according to the Bologna Treaty, the actual level of knowledge and skills can be below the level of regular Dutch students. Moreover, for some (international) students, the lack of prior knowledge is too large and remedial teaching before entering a programme is necessary (Brouwer et al., 2004). In addition, most students are unable to judge for themselves whether they possess sufficient prior-knowledge and/or experience to start a bachelor or master program (Prins, 1997).

In the past, several remedial teaching programs have been developed in the Netherlands. Van Leijen et al. (2005) argues that remedial teaching programs are delivered with varying degrees of success in terms of students completing the program, depending on motivation of students, involvement of teachers and learning environments. In addition, since higher education institutions now have to compete on a European or even global market (Dittrich et al., 2005), regional/national remedial courses in a fixed (physical) location with traditional teaching methods seem inadequate to meet these new challenges. Recent developments in the area of e-learning reduce the limitations of time and place (Vrasidas & Zembylas, 2003) and could therefore help to face these problems.

Based on the experiences from the past and anticipated future changes in higher education in Europe, the University of Amsterdam, the Erasmus University Rotterdam and Maastricht University in collaboration with SURF-foundation, have decided to accept these challenges. The goal of this collaboration is to find successful educational formats focused on flexible remedial teaching in case of a high level of heterogeneity of student intake (Brouwer et al., 2004).

The goals of this paper can be split up into three interconnected parts. First, how can students assess their current level of mastery before joining a (bachelor) program? Second, if the level of mastery of individual students appears to be low, how can online summer courses help to tackle these potential deficiencies? And finally, how can online summer courses be designed to enhance motivation and increase completion rates of students? In this paper, the aspects of successful online remedial teaching are described in a model for online remedial teaching. Afterwards, one of the online summer courses offered at Maastricht University will be used as case-study to show how the online remedial teaching model can be implemented in practice.
2 The online remedial teaching model

According to Bryant et al. (2005), there are many definitions about online and/or distance education. Distance education encompasses two important elements, namely distance teaching and distance learning. Distance teaching regards mainly the way in which instruction is provided, whereas distance learning concerns optimizing student learning behaviour (Keegan, 2002). Various definitions are used for online education. Although in most of the definitions terms like web-enabled and online point at the way instruction is provided, it does not automatically lead to distance education (Bryant et al., 2005). However, in this article the term online (education) is used instead of distance education as the element of distance education is only related to the short time period before students start (physically) at the regular curriculum.

Van Leijen et al. (2004) conducted research in various remedial teaching programs in the Netherlands. A program offered during the summer period induces an incentive problem as most graduated high school students have a strong preference to do other things besides studying. Hence, the challenge arises to construct a programme that achieves a balance between study time and time for summer activities in such a way that it provides sufficient motivation to keep students engaged in the course. Therefore, an institute planning to design and implement an online remedial summer course should consider the following aspects:

1. Accessible & Available 24/7 online: Use of internet helps to overcome the barriers of time and place, and thus enables participants to work anywhere they like and at times that suit them most (Vrasidas & Zembylas, 2003).

2. Adaptive: Each student is in a sense unique. Hence, the programme should ideally allow for an individualized learning path based on prior knowledge, learning style and preferences of the student (Falmange et al., 2004, Abdul-lah, 2003).

3. Rapid feedback: Besides the fact that it is pedagogically better to provide rapid feedback on performance (Draaijer, 2004), it is also important because the period before the course starts is short and often fully planned with other activities. Furthermore, rapid feedback stimulates interaction in an online course (Vrasidas & Zembylas, 2003).

4. Interactive: “A fundamental component of distance education is the communication medium” (Bryant et al., 2003, p. 257). Being solely available online, the course and learning environment should stimulate interpersonal contact in order to motivate participants to remain engaged (Ronteltap & Van der Veen, 2002).

5. Flexible learning methods and assessment: Given the fact that learning and assessment methods are subject to change, the program should be flexible enough (Segers, 2004).
3 Prior knowledge tests and Online Summer Courses in Practice

As most students in the bachelor curriculum of the Faculty of Economics and Business Administration at Maastricht University have (some) problems with Mathematics, the first prior knowledge tests and online summer courses were specifically developed for tackling these problems.

Prospective students of the bachelor studies ‘International Economics’ and ‘International Business’ at Maastricht University were given the opportunity to make an online entry (diagnostic) test in order to assess their prior knowledge of mathematics. The online test was available and accessible 24/7 on the Internet. The test was composed of exercises in open-question type form (Tempelaar & de Gruijter, 2004, Sclater & Howie, 2003). Anyone who filled in the online entry test received elaborate feedback via E-mail from an expert. Overall, the test was viewed 524 times and 230 students made a serious effort to complete the whole test.

Of the 230 students who participated in the entry test, 44% (101) registered for one of the bachelor programs at the Faculty of Economics and Business Administration. Of these 101 students, 55 were willing to invest 60 to 80 hours to remediate his/her deficiency. Those 55 constituted one group of participants of the summer course. A second group of participants of the summer course constituted of prospective students of the Master of Science in Social Protection Financing of the Maastricht Graduate School of Governance. These 18 students were required to take the summer course in order to be allowed in the master program.

The online summer course is based on the server-based tool ALEKS. Students can approach ALEKS through internet; the summer course was delivered in a pure distance format, without any physical contact with lecturers or peers. Lecturers had a limited role: they were available by mail for organizational, tool-related and mathematical issues. The majority of questions sent in appeared to be of the first two categories; the coverage of content material in ALEKS proved to be satisfactory for most students. Participation by BA prospective students was completely voluntary and in no way related to the official admission procedure of the university. The only reward was a (unrecognized) certificate at a graduation ceremony. Moreover, participation in the summer course was free of charge and costs of the course were funded by Maastricht University and SURF-foundation. For the MA prospective students, participation was required.
4 ALEKS

4.1 General Information

The ALEKS system combines adaptive, diagnostic testing with an electronic learning & practice tutorial in several domains relevant for higher education. In addition, it provides lecturers an instructor module where students' progress can be monitored, educational standards can be adapted to a particular college, or course, and other administrative tasks can be carried out. ALEKS is a commercial software product.

4.2 Assessment

The ALEKS assessment module starts with an entry assessment in order to evaluate precisely a student's knowledge state for the given domain (eg. College Algebra). Following this assessment, ALEKS delivers a graphic report analyzing the student's knowledge within all curricular areas for the relevant course, based on specified standards. The report also recommends concepts on which the student can begin working; by clicking on any of these concepts or items the student gains immediate access to the learning module.

Fig. 1. Sample of an assessment item
Some key features of the assessment module are:

- All problems require that the student produce authentic input (that is, there are no multiple-choice questions).
- All problems are algorithmically generated.
- Assessment questions are generated from a carefully-designed repertoire of items ensuring comprehensive coverage of the domain.
- The assessment is adaptive: the choice of each new question is based on the aggregate of responses to all previous questions. As a result, the student's knowledge state can be found by asking only a small subset of the possible questions (typically 15-25).
- Assessment results are always framed relative to specified educational standards. The system allows instructors to customize the standards used by their courses with a syllabus editor (part of the instructor module). Both the assessment and learning modules are automatically adapted to the chosen standards.

4.3 Report

The report provides a detailed, graphic representation of the student's knowledge state by means of pie-charts divided into slices, each of which corresponds to an area of the syllabus. In the ALEKS system, the student's progress is shown by the proportion of the slice that is filled in by solid color: if the slice is entirely filled in, the student has mastered that area, if it is two-thirds filled in, the student has mastered two thirds of the material, and so forth. Also, as the mouse is held over a given slice, a list is displayed of items within that area that the student is currently "ready to learn," as determined by the assessment. Clicking on any of these items gives access to the learning mode (beginning with the item chosen).

4.4 Learning Mode

At the conclusion of the assessment ALEKS determines the concepts that the student is currently ready to learn, based on that student's current knowledge state. These new concepts are listed in the report, and the learning mode is initiated by clicking on any highlighted phrase representing a concept in the list. The focus of the learning mode is a sequence of problems to be solved by the student, representing a series of concepts to be mastered. The facilities offered by the learning mode are as follows:

- Practice (that is, the problems themselves);
- Explanations of concepts and procedures;
- Dictionary of technical terms;
- Calculator (adapted to the topic studied, e.g. in statistical items, a special "statistics calculator" is provided).

For example, a student working on a particular problem may "ask for" an explanation of that problem (by clicking on the button marked "Explain"). The explanation typically provides a short solution of the problem, with commentary.
Fig. 2. Sample of a learning report

After reading the explanation(s), the student may return to "Practice" (by clicking on the button marked "Practice"), where she or he will be presented with another problem exemplifying the item or concept just illustrated. If the student is successful in solving the problem, the system will offer (usually) two or three more instances of the same item to make sure the student has mastered it.

In the text of problems and explanations, certain technical terms such as "addition", "factor" and "square root" are highlighted. Clicking on any highlighted word or phrase will open the dictionary to a definition of the corresponding concept. The dictionary can also be used independently of the current problem to look up any term the student may be curious about.

A graphing calculator is available for computing and displaying geometrical figures in analytical geometry and calculus. Other, related features of the learning mode are Feedback, Progress monitoring, and Practice. Whenever the student attempts to solve a problem in the learning mode, the system responds to the input by saying whether or not the answer is correct and, if it is incorrect, what the student's error might have been.

More generally, ALEKS follows the student's progress during each learning sequence, and will at times offer advice. For example, if a student has read the explanation of a problem a couple of times and yet continues to provide incorrect responses, ALEKS may suggest -- depending on the circumstances -- that the student looks up the definition of a certain word in the dictionary. ALEKS may also propose that the student temporarily abandon the problem at hand and work instead on a related but easier
problem. The capacities of the ALEKS system to monitor and guide student learning is flexible and multi-faceted.

When a student has demonstrated mastery of a particular item by repeatedly solving problems based on it, ALEKS will encourage the student to proceed to a new item.

4.5 Instructor Module

The instructor module enables lecturers to monitor student progress and achievement; to view and change the standards applied in the generation of assessment reports; and to carry out other administrative tasks. In detail, the lecturer can:

- View and print reports for individual students;
- View and print a list of students, with a summary of information for each student including assessment results, progress in the learning mode, and total time spent in the system;
- View and print synthetic reports for entire courses, giving an overview of the class's strengths and weaknesses;
- View the standards used by default for a course, with the option of editing standards pertaining to that course only;
- Edit student registration data or retrieve forgotten passwords.

5 Structure of online summer courses, motivation and impact on regular courses

The most natural way to assess the success of the Summer course is provided by an analysis of the outcomes of the first regular course: Quantitative Methods 1, or QM1.

![Course performance of QM1, decomposed according Summer course participation](image)

**Fig. 3.** Course performance of QM1, decomposed according Summer course participation
The QM1 course is composed of Mathematics, Statistics, and a third but minor part introducing applied computer science. Succession rates amongst Summer course participants are high, and differ significantly from those amongst the non-participants. Of the 29 students who successfully completed the Summer course, 81% pass the QM1 course. For the 26 participants who did not manage to fully complete the Summer course, passing rate is 71%. For the large group of 799 non-participants, passing rate is only 55%; see Figure 3 for a summary of these data. Although students participating but not succeeding the Summer course do remarkably well, those figures are to some extent non-representative, since the proportion of students in this group actually participating in the final exam of QM1, is much lower than in the other two groups: only 7 out of 10 students show up. The combination of exam participation and passing the exam generates the last piece of data: ‘Going and Passing the Exam’. Participating and passing the Summer course appears so to be a strong predictor of the participating and passing the QM1 course.

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<th>QM1 Grade</th>
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Fig. 4. QM1 grades in the final exam, decomposed according Summer course participation and prior Math education
Another expression of the success of the Summer course is found in the confrontation of QM1 course performance of students with different prior Math education, and their participation in the Summer course. As Figure 4 indicates, the heterogeneity in prior education is large: Dutch students can have taken three different types of math prior education, either of minor type (VWO A1,2), or of major type (VWO B1 or VWO B1, 2). German students, constituting about two-third of our student population, either have math taken at GK or ‘Grundkurse’ level, a minor program, or at LK or ‘Leistungskurse’ level, a major program. Further relative small groups are students with an International Baccalaureate (IntBac), and foreign students outside the Netherlands and Germany having taken a national secondary education degree with math either at major or minor level (IntMathMaj and IntMathMin, respectively). Students in our Summer course were all German students (only foreign students were invited, since these students were expected to have the greatest transfer problems), primarily of GK level (30 students), with a small minority of LK level (8 students). The LK students did not improve their passing rates relative to the students who did not participate in the Summer course (84% for both groups); however, the GK level students did make an important jump in passing rate: from 51% to 88%. Or alternatively, expressed in terms of the grade in the final exam (with 5.5 being the floor to get a passing outcome), Figure 4 indicates that students who successfully participated in the Summer course, increased their average grade from about GK level (5.5) to a level (7.3) similar to that of students with a math major in prior education.

The finding that participants of the Summer course outperform non-participants is in itself no proof of the successfulness of the Summer course: there might be a selection bias. If the Summer course attracts a non-representative group of students, such as students being more than average motivated, the effect of participation in the Summer course might be explained by having the best motivated students in this group. To investigate the extent in which the increased success rate in the exam can be attributed to a selection bias component at the one side, and a real learning effect of the Summer course at the other side, the partial math and statistics scores in the final QM1 exam of Summer course participants and non-participants are confronted. Figure 5 provides a graphical depiction of these data. Summer course participants indeed do better than non-participants in both math and statistics, but their advantage in math is much larger than their advantage in statistics. In fact, the only statistically significant difference in partial exam scores is the math score of student passing the Summer course, and the math score of non-participants. So if any selection bias is present, the effect it causes is small, statistically insignificant and surpassed in size by a true learning effect.

A second check on the presence of a selection bias caused by motivational differences is provided by ALEKS study time data of students working in the ALEKS business Statistics module during the course QM1. Whereas a small group of students used the ALEKS College Algebra module during the Summer Course on voluntary basis, all students used the ALEKS Business Statistics module in the QM1 course in order to practice and prepare for their statistics quizzes. Study time (logon time) in ALEKS Business Statistics might therefore be regarded as a good proxy for student motivation. Figure 6 contains the study time data for students with different prior education levels, and Summer course participants.
If anything, Summercourse participants study less than students in their reference group, the students with a GK prior education. Most striking is the large difference in study time between Dutch and foreign students.
Therefore, neither partial scores, nor study time, suggest the existence of a strong selection effect, thus suggesting that the increased course performances of Summer course participants can be attributed to a true learning effect.

In total 72 students filled in the evaluation at the end of the course; see Table 1. On a scale from 1 to 10, students were very positive about both the functioning of the tool (8.6) as well as the online summer course as such (8.8). More specifically, on a Likert scale from 1-5, students felt that the course had offered them a lot (4.6) and enabled them to remediate their knowledge to such an extent that they feel ready to start in Maastricht (3.7). Remarkably, the evaluations of students failing the summer course are similar to those passing the summer course.

<table>
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<th>Table 1. Evaluation of Online Summer course Mathematics</th>
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<td>This Summer course offered me a lot</td>
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<td>The contents of the Summer course were inspiring</td>
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<tr>
<td>The format of the Summer course was good</td>
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<tr>
<td>The Summer course was well organized</td>
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<tr>
<td>The quality of the material in ALEKS is good</td>
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<tr>
<td>The material in ALEKS motivated me to keep up with the subject matter</td>
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<tr>
<td>Learning in an e-learning environment as ALEKS is not different from learning from a hard-copy book</td>
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<tr>
<td>It was fun that I could attend this Summer course via the internet</td>
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<tr>
<td>I gained enough knowledge and skills in mathematics to start with my study in Maastricht</td>
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<tr>
<td>It was easy to motivate myself to finish this Summer course</td>
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<tr>
<td>It was good that I could work on the subject matter at my own pace</td>
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<tr>
<td>I think that I have learned more by individually attending this course than I would have learned if I had to collaborate</td>
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<tr>
<td>Questions via e-mail were answered well by the teacher</td>
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<td>Give an overall grade for the quality of support you were given by ALEKS in this Summer course (1 = very bad - 10 = very good)</td>
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6 Conclusion and Discussion

In this paper, the question how prior knowledge tests and online remedial teaching courses can contribute to mitigating the problems of heterogeneous enrolment of students was dealt with. First of all, an online remedial teaching model was developed. The five success factors, which an online remedial course developer should take into account, are 24/7 access and availability on Internet, adaptiveness, rapid feedback, interactive, and flexible learning methods and assessment. Next, the online remedial teaching model was implemented in practice at the online summer course of Mathematics at Maastricht University. Both learning outcomes, as evidenced in regular course performances and evaluations at the end of the course were very positive. On average, students were highly motivated to remediate their knowledge gaps and they worked approximately 70 hours for the entire course. Furthermore, students indicated that they now have more confidence of making a good start at the institute. Exactly half of the group of students that started with the course eventually received a certificate.

The case-study of the online summer course Mathematics and the experiences from other courses offered by the three institutions taking part in the project “Web-spijkeren” indicate that it is possible to construct an online course that continuously motivates students and thereby increasing passing rates. The online course was build with existing ICT-structures that are also available at other institutions. If an institute provides accurate means and expertise for establishing an online summer course program, it should be possible to mitigate the problems with increased heterogeneity of enrolments of students.

Further research is necessary to prove whether online summer courses have a temporal or structural effect on the (prior) knowledge level of students. In addition, it remains to be investigated whether the participants, in comparison to those who did not take part at the summer course, perform better in the respective courses in the curriculum. Further research efforts are focused on the relationship between student characteristics and performance in the summer course, such as students’ preferred learning styles, their metacognitive abilities, and their level of achievement motivation.

References